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MONITORING AND CONTROL SYSTEM FOR SEWAGE SLUDGE DISPOSAL PLANT

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I. FOREWORD

In Japan, about 80% of the sewage sludge is currently used for reclamation. However, urbanization is progressing and it is becoming more difficult to acquire suitable place for this purpose. In this meaning, the reduction of sludge is being pursued. Dedicated sludge treatment facilities are also appearing as one means of solving this sludge treatment problem. As sludge treatment is becoming advanced, its monitoring and control has become important.

Based on our supply experience and accumulated know-how, the overall contents of monitoring and control systems for sewage sludge disposal plant are introduced.

II. SYSTEM ARCHITECTURE TECHNOLOGY

The systemization of monitoring and control in sewage treatment plants is remarkable, and is even being extended to sludge disposal plants. In particular, as sludge disposal plants have become larger, their operation control has become extremly complecated. On the other hand, from the demand for energy and labor saving, a system which quickly and accurately transmits a large volume of information to the operator and which can be operated with few people is desired.

In many cases, sludge disposal plants are operated and controlled independently of sewage treatment plants. Besides, since the configuration elements and characteristics of the process are different, the incinerator has been separated and an independent control room has also be built. These are due to the following features of sludge disposal plant operation and monitoring.

(1) Operation and maintenance personnel must have a special knowledge of processes and machinery.
(2) Batch operation and continuous operation are mixed, and switching from automatic operation to manual operation and from manual operation to automatic operation during maintenance is frequent.
(3) Since heavy oil or gas are used as supplementary fuels and chemicals are also used in exhaust gas processing, safe operation is demanded.
(4) Operation and maintenance are mostly entrusted to specialists.

Advances made in microprocessor technology in recent years have led to the development of various monitoring and control apparatus and have made possible the construction of a system matched to the needs of users.

The following introduces on example of the system configuration at a large sludge disposal plant baced on recent deliveries.

2.1 Basic design policy

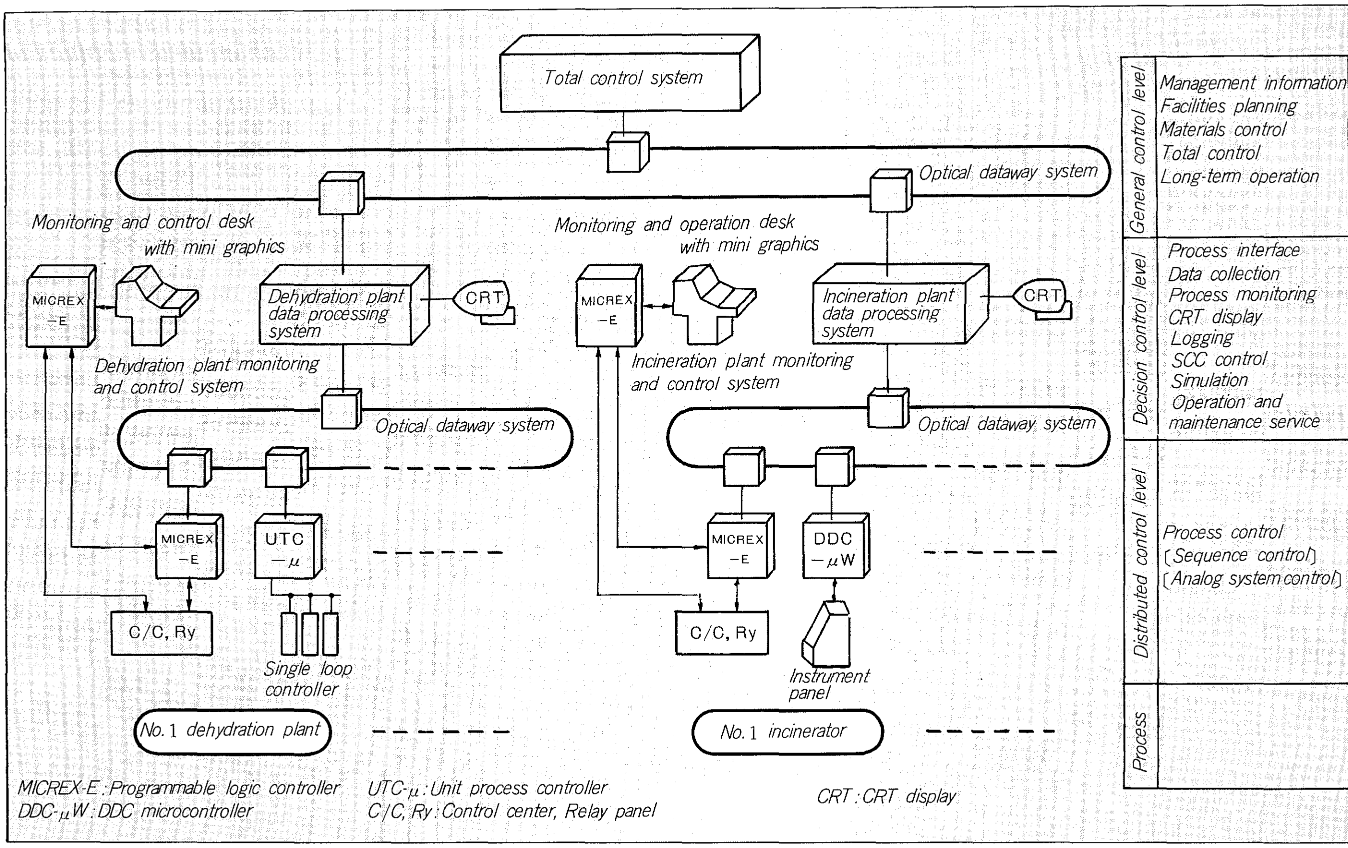
In the case of sewage treatment plants, when building a system, monitoring and operability and stable control of the process are important decision elements. In particular, since sludge incineration facilities are plants which handle heavy oil and gas, consideration must be given to safety. Furthermore, since they resemble chemical plants in that the amount of information from the process is large, the construction of a monitoring and control system in which attention is given to safety, flexibility, etc., and total system balance including the plant is considered is demanded.

2.2 System configuration

The elements of a sludge disposal plant differ substantially with the disposal process and are also grouped into blocks in the process, and operation, maintenance, expansion, and repression on a block basis are possible. Therefore, distributed control is suitable. Moreover, since the disposal processes are connected in series, reliability and safety are demanded of the system and a system construction method such that damage of one part does not affect the total system is demanded. For this reason, a hierarchal central monitoring and distributed control system is employed.

Moreover, besides the normal route; on-site programmable logic controller (PLC)→ dataway → data processing system, the signal system from the local panel to the monitoring system has a direct route from local panel to the monitoring and operation desk which is controlled by dedicated PLC. Then the minimum monitoring functions to maintain safe plant operation even if a fault occurs in

Fig. 1 Large system configuration example



the system is secured.

Fig. 1 is an example of the system configuration at a large scale sludge disposal plant. The system functions are grouped into general control level, decision control level and distributed control level and has a hierarchal construction. The total monitoring system is positioned at the general contorl level and management data processing, facilities planning, materials control, etc. for the entire plant are performed totally.

This system has a dehydration plant monitoring and control system and an incinerating plant monitoring and control system as subsystems. Both subsystems are positioned under the total control system which monitors and controls the entire plant and are connected with the optical dataway.

In the dehydration plant and the incineration plant systems, a computer system is at the center and the PLC (MICREX-E), unit process controller (MICREX UTC-μ), DDC controller (MICREX DDC-μW), etc. are connected by a dataway. The dataway uses a high speed optical dataway (MPCS-F) and is extremely reliable.

The data processing system at the decision control level uses a graphic display, Chinese character printer, hard copy, etc. as the man-machine interface.

The distributed control level is the interface with the process, and performs direct control. Therefore, functions matched to the process must be used. The condensation, digestion, and dehydration processes are batch processes. The incineration process operated on schedule when it starts and stops, and continuous when usual. In these processes, linked starting and stopping control, intermittent control, and planning control are performed frequently and the introduction of a PLC is effective.

A DDC control system is used in the analog control system. In the dehydration plant, maintenance and expansion at each block corresponding to one dehydrator is considered and DDC and data transmission are performed by connecting a single loop controller (Compact Controller F) and unit process controller (MICREX UTC-μ). At the incineration plant, a 32 loop type DDC microcontroller (MICREX DDC-μW) corresponding to one furnace is used so that advanced SCC control by data processor is performed. Moreover, for safety, an instrument panel containing backup devices is installed.

2.3 Main-machine interface

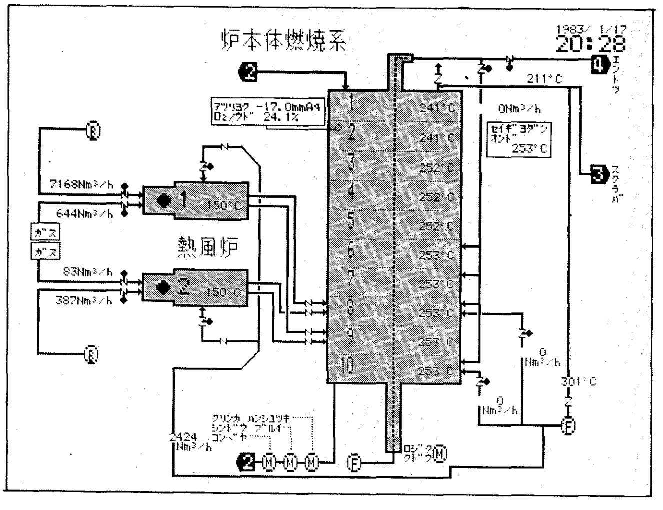
The man-machine interface (MMI) is the data exchange system of operators and maintenance personnel with process. Its quality governs the ease of plant operation control. MMI devices are data processor, monitoring and control desk (with mini graphics), instrument panel, etc. However, the main device is a CRT display. A typewriter, X-Y plotter, hard copy, and other devices are also used according to the application. *Table 1* shows the functional load.

(1) Monitoring and operation desk

Table 1 Man-machine interface devices functions sharing

	CRT	Monitoring and operation desk	Instrument panel
Monitoring functions	◦ All data can be displayed. ◦ Easily understood data presentation possible ◦ Processed data can be displayed.	◦ Main states of process can be grasped with mini graphics. ◦ Display of important data	◦ Indicator, integrator, and recorder installed as CRT data display back-up.
Control functions (operation functions)	◦ Input of setting values, parameters, constants, etc. by CRT and keyboard ◦ Operation by light pen	◦ Individual operation of important equipment ◦ Totally linked operation ◦ Emergency stop	◦ Controller operation
Recording functions	◦ Daily report and monthly report printing, alarm report generation, alarm printing by Chinese character printer		◦ REcording by dedicated recorder

Fig. 2 CRT display display example



To effectively use the control room space, improve comfort, etc., the large scale graphic panel is eliminated, a mini graphic panel to grasp the total process is installed at the operation desk, and the desk is made an operation desk by adding monitoring functions.

The main operation functions are operation starting and stopping of the total plant and backup operation when the system is abnormal. Reliable backup data and operation signals are realized by installing a transmission route independent of the optical dataway.

(2) CRT display

Several 4,000 character graphic displays are installed and functions are assigned to each CRT.

Moreover, when a failure occurs, the CRTs back up each other and reliability is improved.

The CRT display uses Chinese character extensively to display alarm messages, loop names, and various signal names.

A CRT display example is shown in *Fig. 2*.

(3) Chinese character printer

Chinese character is used in daily reports, monthly reports, and alarm messages and quality and operator visibility have been improved tremendously.

(4) Instrument panel

This panel mounts back-up instruments so that safe plant operation can be maintained even if the system is abnormal.

2.4 Data processing functions

The functional configuration of the data processing system positioned at the decision control level is shown in *Fig. 3*. The features of this functional configuration are described below.

(1) Data base oriented

The data processor has direct input/output data and dataway transmission input/output data. The volume of this input/output data is extremely large. To efficiently collect, efficiently display and print, and efficiently control these data, a data base system is introduced. This consists of input/output data (pridata) and generated and edited secondary data. The introduction of this data base makes arbitrary combination of the items which are displayed on the same screen of the CRT according to the operating mode, arbitrary recombination of the daily report and monthly report printing items, or arbitrary modification of the data processing specifications even by the user easy. Moreover, it is also flexible enough to cope with software expansion and reconstruction due to plant expansion and reconstruction.

(2) Completion of interactive functions

The interactive functions are clearly grouped into "operation level" with the operator as the objective, "engineer level" with the design engineer as the objective, and "system engineer level" which requires a detailed general knowledge of software and is easy to use without any errors.

The center of the interactive functions is the CRT display, and data arbitrary reassembling, control parameters and constant setting, interactive view panel generating etc. are performed easily.

(3) Process analysis function

Attention is focussed on the unknown parts of the sludge disposal process and on the incomplete field of control techniques, and to positively solve these problems, analysis control functions such as the following are developed and supplied to the user.

(a) Multi-stage incinerator operation simulation function
(b) Sludge disposal SCC control function
(c) Time series data collection and display function (trend display)

Fig. 3 Data processing system functional configuration

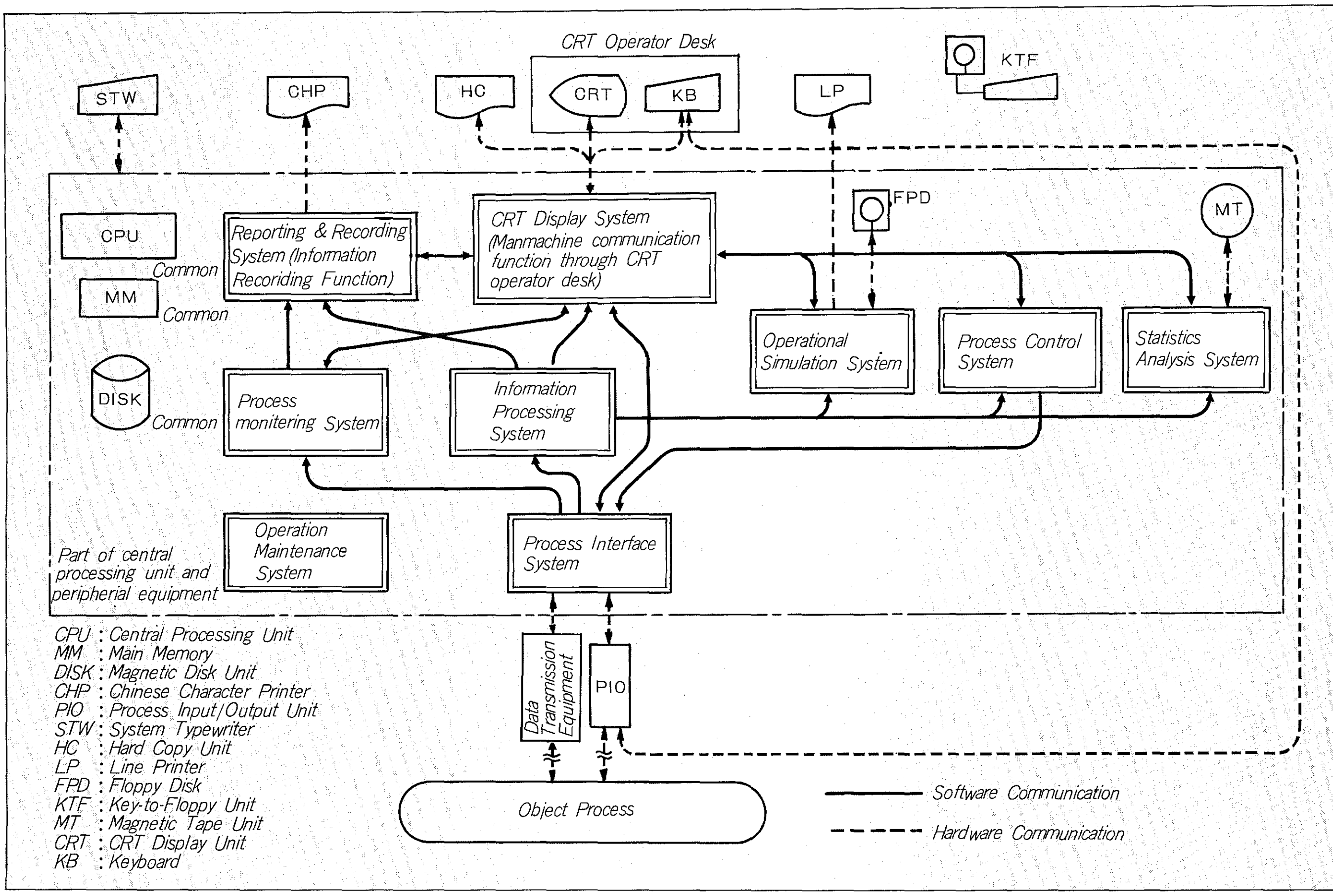


Table 2 MPCS-F optical transmission outline specifications

Classification	Item	Characteristic
Transmission performance	Transmission speed	12.6M bits/sec
	Transmission distance (1 span)	1.5 km
Optical fiber	Mode	Multi-mode (SI)
	Loss	4 dB/km (0.85 μm)
	Transmission band	<40 MHz·km
	Core diameter	62.5 μm
	Cladding diameter	125 μm

2.5 Data transmission technology

In monitoring and control systems in sludge disposal plants, the data transmission sources are scattered in facility block units and the volume of data is large. Moreover, electrical noise level is high, the transmission cable is frequently installed in parallel with the power receiving and power facility cables, and other electrical disturbances are prevalent. However, by using an optical transmission system, a high speed, efficient, highly reliable data transmission, resistant to electrical disturbances can be realized by utilizing the (1) wideband characteristics, (2) low loss, (3) electrical isolation, (4) non-inductance, (5) explosion-proofing, (6) light weight, thin, flexible, and other features of the system.

Table 2 outlines the specifications of the Fuji optical dataway system. MPCS-F is designed to be fault tolerant and to have complete RAS functions so that local faults do not effect other parts, in addition to having the features described above. And this is suitable as a sludge disposal total management system dataway.

III. PROCESS CONTROL FUNCTIONS

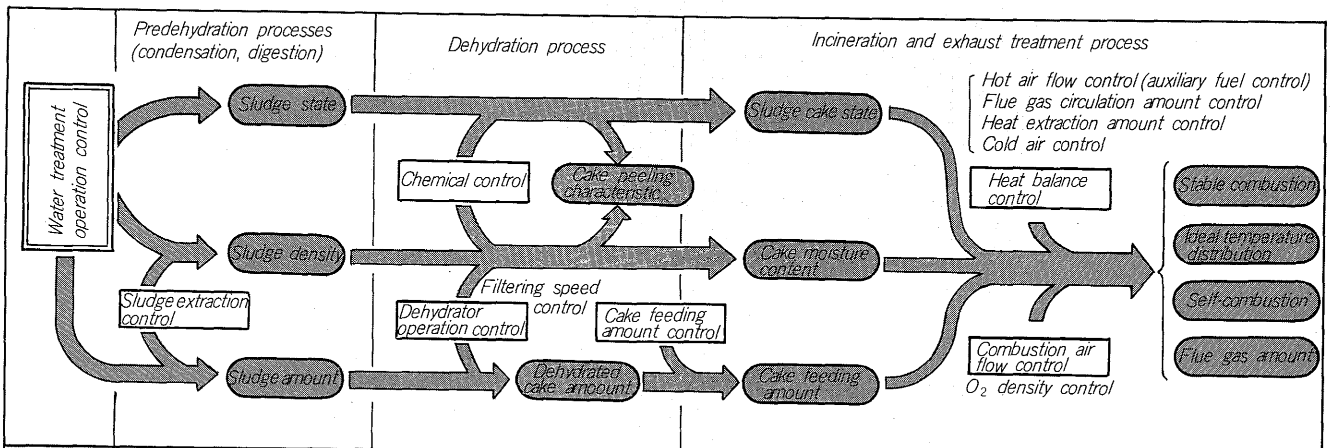
In the past, sludge disposal process control was mainly sequence control by relay circuits and analog control was a simple PID control level. However, today process control technology has been systemized and composite control which combines sequence control and analog control and advanced control incorporating feed forward, etc. is being gradually implemented. The connection of each process, the control objectives, and the main control items are summarized in *Fig. 4*. Of these, incineration is described below as a typical example.

Furnace internal combustion control consists of heat balance control and combustion air flow control.

3.1 Heat balance control

To maintain the optimum furnace internal heat balance, a configuration in which controls associated with heat support do not interfere each other is necessary.

Fig. 4 Process control system flow



	Predehydration processes (condensation, digestion)	Dehydration process	Incineration and exhaust treatment process
Sequence control	*Sludge collector sequence* *Sludge extration sequence*	*Sludge conveying sequence* *Chemical mixing sequence* *Dehydrator sequence*	*Cake feeding system* *Furnace treatment system* *Exhaust treatment system* *Ash conveying system* *Flue gas denitration and deodorization system*
Process control	*Concentrated sludge extraction control* *Digester internal temperature control* *Digester internal pH control* *Digester gas generation amount control*	*Constant sludge feeding amount control* *Sludge feeding amount proportional chemical feeding control* *Sludge feeding matter content proportional control* *Cake moisture content control*	*Cake feeding amount control* *Hot air amount control* *Flue gas circulation amount control* *Furnace internal pressure control* *Reheating furnace temperature control* *Exhaust processing system pH control*

(1) Hot air flow control

The desired combustion control stage temperature is obtained by supplementary fuel control.

(2) Flue gas circuit amount control

Low combustion air ratio operation is performed by circulating the flue gas and the temperature is controlled by combustion suppression.

(3) Heat extraction amount control

Control which returns the heat balance of each stage inside the furnace to the normal region by extracting the surplus heat to the outside from the combustion stage or drying stage.

3.2 Combustion air flow control

(1) O_2 density control

Since noncombustion gas is exhausted if the furnace internal O_2 density becomes low, shaft cooling air circulation amount control by O_2 density is performed.

(2) Self-combustion control

When high calory sludge reaches the self-combustion state, the auxiliary fuel system is turned off and the the supply of the amount of air necessary for self-combustion is controlled.

IV. VERTICAL MULTISTAGE INCINERATOR SLUDGE COMBUSTION SIMULATION

4.1 Simulation functions

There are two sludge combustion simulation system: offline batch system by large computer and online system using a control computer. Both systems consist of:

(1) Sludge cake combustion static simulation
(2) Sludge cake combustion dynamic simulation
(3) Sludge cake combustion control simulation

Both systems have the following objectives:

(1) Static simulation obtains the long-term operation and control index by finding the normal combustion state.
(2) Dynamic simulation analyzes the transition of the sludge cake combustion state by changing the operating conditions.
(3) Control simulation is used to study and develop control system and to perform parameter identification and validity evaluation by performing simulation including control operation under various operating conditions and to forecast changes in the combustion state of the incinerator and to acquire guide data to perform safe and suitable operation control at the actual plant.

To achieve these objectives, the systems have the following functions:

(1) Sludge feeding amount, moisture content, combustible component ratio, combustible component composition ratio setting, disturbance operation.
(2) Hot air flow, shaft cooling air and flue gas circulation amount, cold air flow, combustion gas extraction amount, etc. setting and various control operations.
(3) Calculation of combustion gas temperature and residual oxygen density of each stage of the incinerator.
(4) Judgement of the drying, combustion, and cooling state and calculation of the moisture content and heat

Fig. 5 Configuration of online simulation system

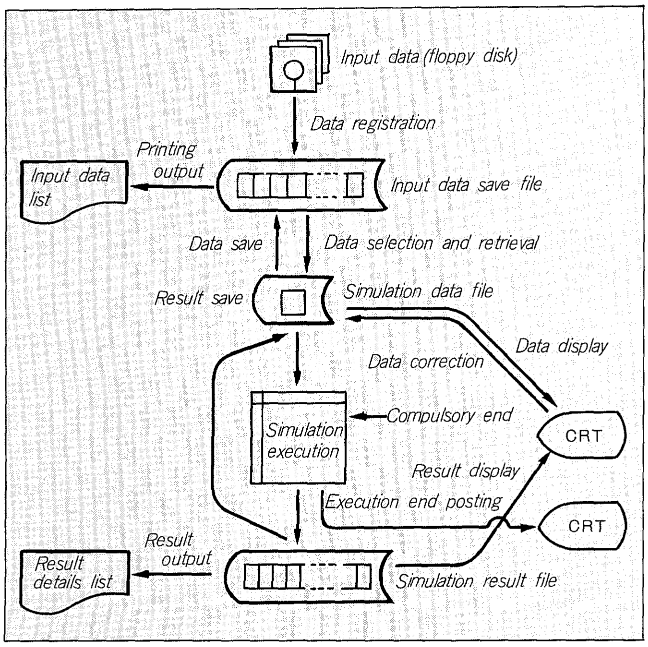
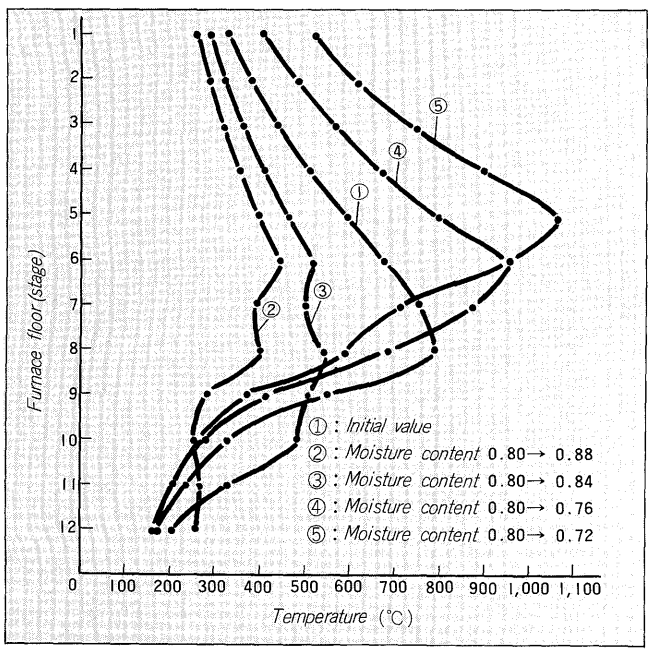


Fig. 6 Temperature distribution after 240 minutes from moisture content change



output of the sludge cake at each stage of the incinerator.

(5) Judgement of the self-combustion stage of the sludge cake at each stage of the incinerator.

A model which allows description of the each process up to counterflow contact of the sludge cake placed in the incinerator with the hot air and cold air and discharge through drying, combustion, and cooling is necessary. For this reason, the thermal balance and matter balance of each state are calculated with model equations which describe the sludge cake drying and combustion processes with the sludge cake assumed to be made up of combustibles, ash, and water components and combustion gas organization as dry gas and steam. The changes of stage of the sludge cake and combustion gas can be simulated by this.

4.2 Online simulation system configuration

A configuration example is shown in *Fig. 5.* This system is constructed so that the actual plant operating stage and the various operation values data can be easily set and the result of simulation can be output in a form that can be used in actual operation.

Sludge combustion simulation can be used to study and develop:

(1) Feed forward control by sludge cake feeding amount and state.

(2) Low air ratio operation to save energy and resources.

(3) Control of the hot air flow, flue gas recirculation, combustion gas extraction, etc.

It can also be adopted to online SCC control by model improvement and improvement and development of the sensor which detects the state of the sludge cake and the state of combustion in the furnace.

Fig. 7 shows the results of simulation of the state of the the combustion gas after 240 minutes when the moisture content was changed from the normal state (moisture content 0.8, cake feeding amount 250 t/d).

V. CONCLUSION

In Japan, sewage sludge disposal plants are in the age of construction and we are confident of our monitoring and control system which stresses greater harmony with man through the introduction of new technology and new equipment.